MONTHLY WEATHER REVIEW

Editor, JAMES E. CASKEY, JR.

METEOROLOGICAL CHARTS IN THREE DIMENSIONS

ALBERT V. CARLIN

U. S. Weather Bureau, Washington, D. C.
[Manuscript received April 23, 1954]

ABSTRACT

A method is described by which constant pressure contour charts can be drawn as stereographic pairs. These charts are then made into photographic slides which may be viewed in a stereoscope or projected on a screen to produce three-dimensional representations of constant pressure surfaces. Two or more pressure levels can be drawn on the same charts and will appear to be separated in vertical space when viewed. Other types of meteorological charts and graphical representations are amenable to this treatment.

INTRODUCTION

A review of a few principles of stereoscopic vision will be necessary as an introduction to make clear the process by which three-dimensional meteorological charts have been constructed. The main basis of three-dimensional vision is the fact of having two eyes, separated by a fixed distance. Each eye sees a slightly different image—the left eye sees a bit more of the left side of an object, and vice versa. In addition to this effect, which allows us to see "roundness," the angle subtended at the eyes by a distant object is smaller than the angle subtended by a nearer object. In other words, the distant object looks smaller. This is usually described as the effect of perspective.

Perhaps more important than these considerations, however, at least for stationary objects, is the effect of parallax which is the result of the fact that the two eyes are separated by a certain distance. Stereoscopic parallax can best be defined with reference to figure 1.

For simplicity, let us assume we have cameras instead of eyes, the left camera at L_1 and the right one at L_2, the lenses separated by a distance B. To save space, we have shown the film plates F_1 and F_2 in front of the lenses instead of behind, where they of course would be in order to take pictures; geometrically, however, the relationships would remain the same. Let f be the focal length of the lenses; H and ΔH are distances as indicated. Now the
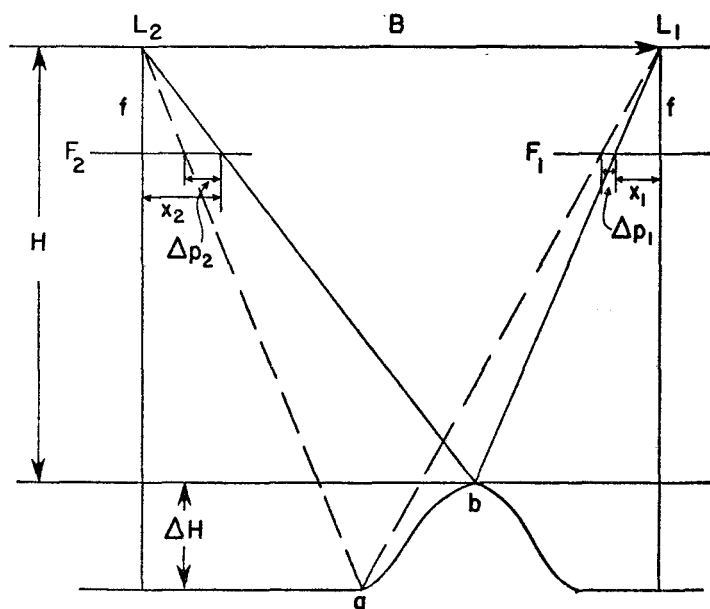

FIGURE 1.—Diagram illustrating the principle of stereoscopic parallax. See text for explanation.

stereoscopic parallax, p, is defined by the relationship $p = x_2 - x_1$, where values of x_1 and x_2 are taken positive to the right of the lens axes, negative to the left. The parallax difference is $\Delta p = \Delta p_2 - \Delta p_1$.

By simple geometry, it can be seen from figure 1 that $p/B = f/H$. Further, the difference in elevation ΔH,

between two points a and b is related to the parallax difference by the following approximate equation:

$$\Delta H = -\frac{Bf}{p^2}\Delta p = -\frac{H^2}{Bf}\Delta p.$$

Thus, the quantity Δp, or parallax difference, determines the apparent height of the two points as measured from the two photographic plates F_1 and F_2.

It seems likely that the brain somehow is able to interpret the parallax difference sensed through the images on the retinas of the two eyes as a height or depth difference.

CONSTRUCTION OF CHARTS

These simple principles of stereoscopic vision are used in constructing two views of a contour chart which together will give the appearance of relative depth to the chart. In general it may be expected that in the two separate charts, the total parallax difference between the two lowest contours would be less than that between the lowest and the highest contours. Since the contour height interval is constant, the parallax difference between any two consecutive contours is constant to a very close approximation.

This principle was used in drawing the charts shown in figures 3, 4, and 5.[1] The process may be described in a step-by-step procedure.

1. On a light table, trace the contours from the manuscript map onto a blank map. If possible, this should be done in ink.
2. Remove the manuscript map and attach the copy to the light table by means of tape.
3. Place a blank map over the contour map which was attached to the light table, and match the maps exactly, center on center, and also laterally and longitudinally.

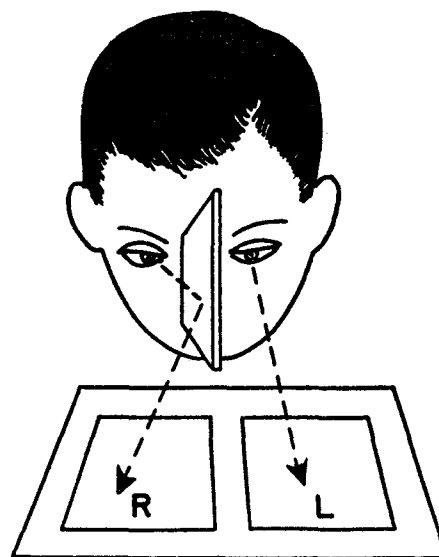[1] See figure 2 for instructions for viewing these charts in 3-D.

FIGURE 2.—Method for viewing figures 3, 4, and 5. A little practice may be necessary the first time one tries to view stereoscopic pairs by this method. Hold a small mirror along the right side of the nose, shiny side to the right. Bend over the page as shown above, being sure to keep both eyes open. The left eye will see the left picture (L) and at first the right eye will see different things reflected in the mirror. Tilt the mirror slowly until the reflection of the right picture is seen by the right eye. Then tilt the mirror farther until the right picutre overlaps the left one. Once perfect overlapping is achieved, the two views will fuse clearly into a three-dimensional view.

4. a. If the lowest contour is at "sea level," trace it exactly, with exactly the same width of line. If the numerical value of the contour is printed on the original chart, trace this lettering exactly also.
   b. Next, move the top (or blank) chart one millimeter [2] to the right, keeping the charts in lateral alignment.
   c. Now trace exactly the next higher contour, and trace also its height value, if desired.

[2] This displacement, or slightly smaller, works well for charts about 28 in. x 32 in. in size. Larger displacement exaggerates depth. For smaller charts, use proportional displacements. It is obvious, of course, that in order to show depth adequately in constant pressure contour charts, the depth dimension is exaggerated compared to the horizontal dimensions of the maps.
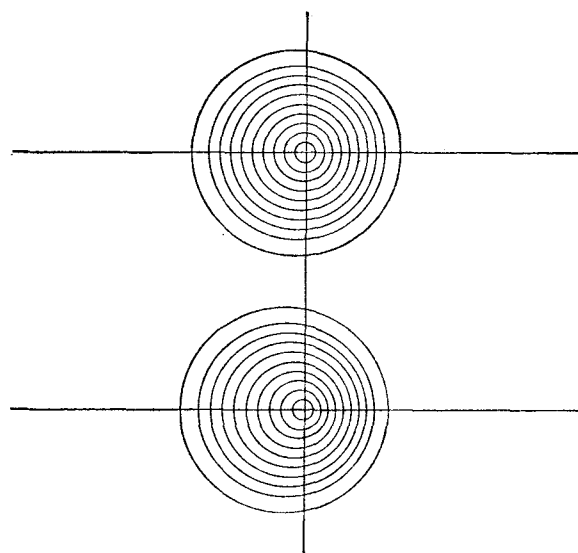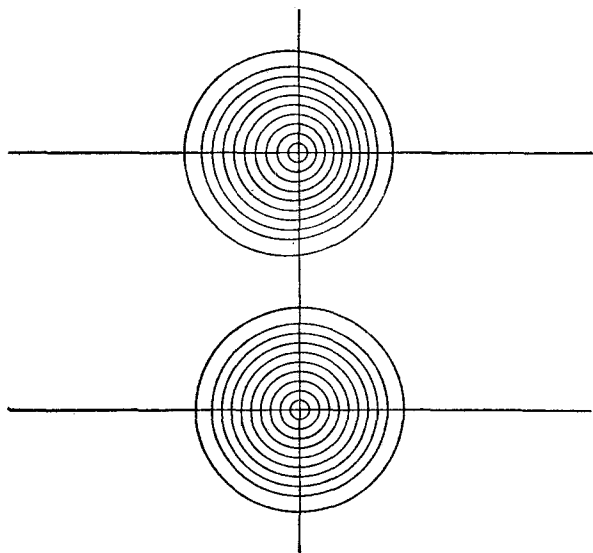
FIGURE 3.—Illustration of distortion in a stereoscopic diagram. To view in 3-D, follow instructions given under figure 2.

d. Continue this process, moving always one millimeter to the right before tracing the next higher contour.

Note: (a) The displacement may equally well be made to the *left*, but once the direction of displacement has been decided, it must be continued in that direction for each higher contour. The direction of displacement merely governs the way in which the final product is viewed or mounted in slide mounts.

(b) If some of the contours are *below* "sea level," (as on some 1,000-mb. charts) the direction of displacement for these contours should be opposite to that for those above sea level; i. e., if displacement for contours above sea level is to the right, then displacement for those below sea level should be to the left, starting with centers of charts exactly matched.

(c) Amount of displacement may remain the same for each contour. This gives negligible distortion in most cases. The amount of displacement generally found useful is one millimeter for each successive contour. Increasing this amount of displacement steepens the appearance of ridges and troughs. Thus the amount of exaggeration may be controlled.

5. If the lowest contour is some height above "sea level," the blank map should be moved to the right a proportional amount (one or more milli-
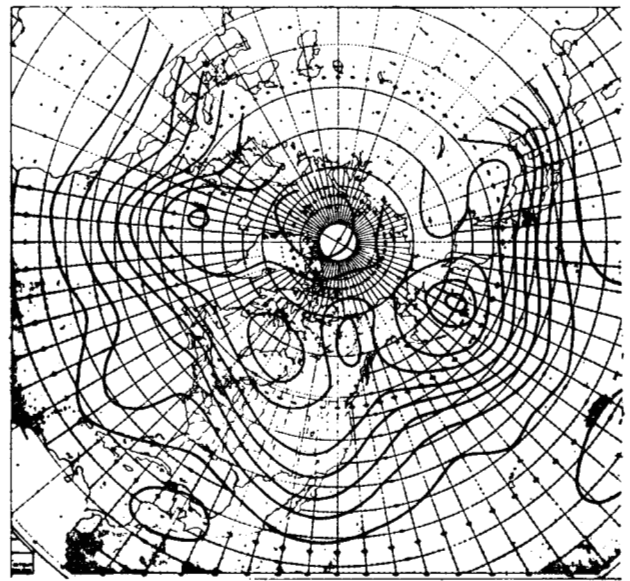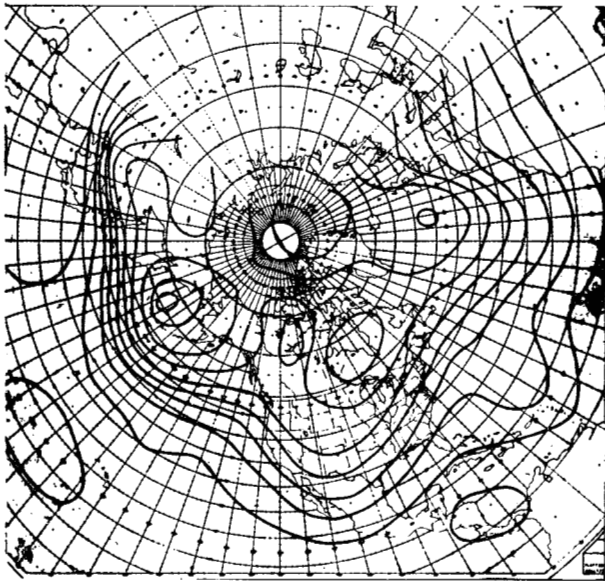

FIGURE 4.—A 5-day mean 200-mb. chart in 3-D. The depth dimension is very greatly exaggerated in this view in order to demonstrate its three-dimensional characteristics. Parallax difference between contours is 4 millimeters.
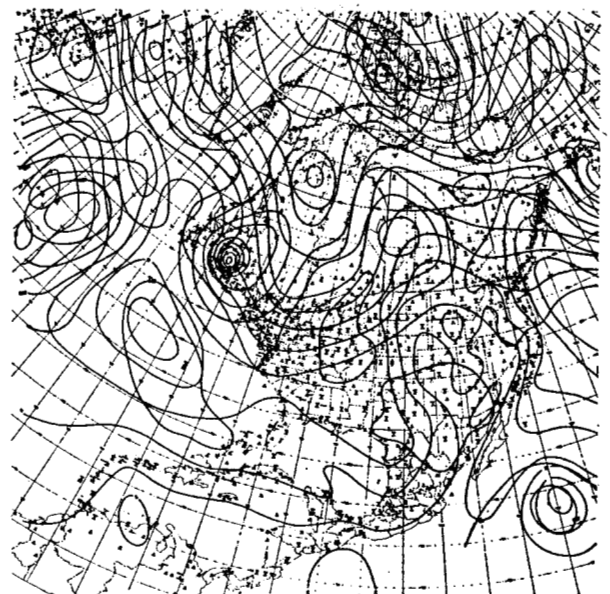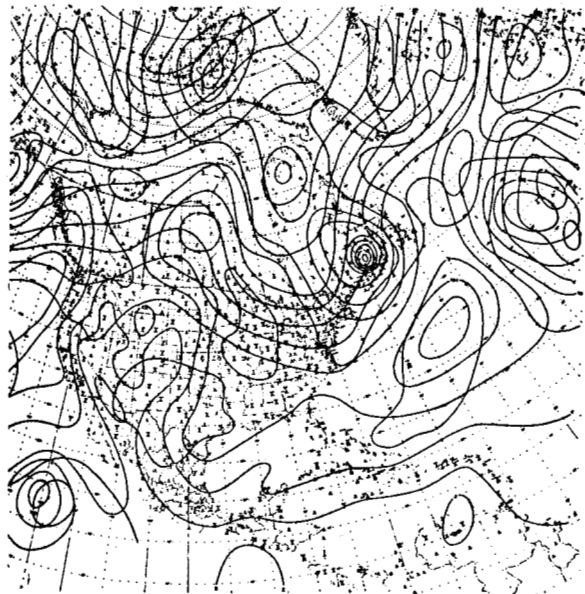

FIGURE 5.—The 1000-mb. and 500-mb. contours for September 8, 1953. Parallax difference between contours is one millimeter.

meters) before the first contour is traced. Following this, the other contours are traced according to the process described in item 4 above.

It is to be noted that the distinctive feature of this process by which figures 4 and 5 were drawn, is that all of the stereoscopic parallax is drawn into the second, or "derived" chart. This greatly simplifies the preparation of 3-D charts, and the distortion is negligible in most cases. Figure 3 was drawn so as to give just about the maximum distortion possible in the bottom cone. The top cone was drawn by introducing half of the parallax in each view, so that there is no distortion. This can also be done on contour maps in the first step. To do this, instead of tracing the manuscript map exactly, the blank map should be moved *one-half* a millimeter to the *left* for each successively higher contour. Then, steps 2 through 5 may be followed to complete the process.

After the second, or "derived" chart is drawn, both charts are photographed, with the proper reduction so as to fit into a stereoscopic slide binder. Effort can be saved if the charts are photographed by means of a conventional 35 mm. stereoscopic camera, for then the correct frame size will be obtained automatically, and the transparencies can be mounted directly in conventional stereo-mounts for use in currently available stereoscopic projectors or hand viewers. If black and white photographic film is used, transparent positive slides are made from the negatives. If color film is used, the slides may be made directly from it.

If the "derived" chart is displaced to the right for consecutively higher contours, then the "derived" chart will be the right-hand component of the stereographic pair of views. If the displacement is to the left, then the "derived" chart will be the left-hand component of the two views.

CONCLUDING REMARKS

This process for constructing stereoscopic pairs can be utilized for all types of charts which depict surfaces or solid objects by means of contours. This includes imaginary surfaces such as those depicting magnetic fields, isentropic surfaces, constant pressure surfaces, etc.

In addition, any three variables (such as two independent and one dependent variable) which may be represented by families of lines (contours) can be subjected to this graphic process so as to appear in three dimensions. Lettering or printing can also be drawn so as to appear in three-dimensional space.

ACKNOWLEDGMENTS